SITE-SPECIFIC RISK ASSESSMENT OF THE SOUND-SORB BERM AT THE OSHAWA SKEET AND GUN CLUB, OSHAWA, ONTARIO

FINAL REPORT

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1.0 INTRODUCTION

Cantox Environmental Inc. (CEI) was retained by the Ontario Ministry of the Environment (MOE) to conduct a site-specific risk assessment on the Sound-Sorb berm at the Oshawa Skeet and Gun Club (OSGC) in Oshawa, Ontario. The OSGC, further referred to as the "site", is located at the crest of the Oak Ridges Moraine, on Lots 4 and 5, Concession 9, in the City of Oshawa, Ontario. However, the focus of this risk assessment is the Sound-Sorb berm, not the entire OSGC site.

Concerns have been expressed by local residents regarding the use of Sound-Sorb for the construction of the berm at the OSGC, prompting the initiation of the current site-specific risk assessment (SSRA). Concerns included the potential for adverse effects to human health and the environment that may result from significant microbial activity within the berm as well as the potential for substances to leach into the groundwater. Some of the substances of particular concern to the residents and citizen's groups include total petroleum hydrocarbons (TPH), various bacteria, and the acrylamide monomer. The objective of the SSRA was to evaluate any potential impacts to human health or the environment resulting from the use of Sound-Sorb for the construction of a sound and bullet attenuation berm at the OSGC. The SSRA considered the impacts to humans, wildlife, invertebrates and vegetation, both on and off the site, of various substances that may have originated from the berm. The SSRA is not intended to address other concerns related to Sound-Sorb or its use at other gun clubs, or the impacts associated with the use of compost.

Additional concerns were raised by non-governmental organizations (NGOs), including Protect The Ridges (PTR) and Sierra Club. CEI met with representatives of these organizations, as well as a consultant (Premier Environmental Services Inc.) that is advising PTR. Several questions, comments and recommendations by these NGOs have influenced the scope of the work in this SSRA, specifically related to: TCLP analysis of berm samples to identify other substances of potential concern (see Section 2.4.2); a groundwater pump test to determine groundwater velocity and connections between shallow and deep aquifers (see Section 2.2 and Appendix A); and, consideration of surface water resources in the area (see Section 4.1).

The SSRA is comprised of the following sections: Introduction (Section 1.0); Review of Site Characterization Data (Section 2.0); Human Health Risk Assessment (Section 3.0); Ecological Risk Assessment (Section 4.0); Conclusions and Recommendations (Section 5.0); and References (Section 6.0). The complete hydrogeological report for the site is provided in Appendix A. Correspondence with the Aurora District Office of the MNR regarding sensitive ecological resources around the OSGC is provided in Appendix B. Tables containing the site data used for the identification of substances of potential concern are included in Appendix C. Correspondence in reference to peer review and Standards Development Branch (SDB) review of this risk assessment is included in Appendix D. A marked up version of this report, showing all changes to the March 11, 2005 draft report are included as Appendix E.

2.0 REVIEW OF SITE CHARACTERIZATION DATA

Several investigations have been conducted at and around the OSGC. The majority of these investigations have been conducted by the MOE and/or on behalf of the Ministry. The discussion of these investigations and the resulting data is divided into four sections. A general description of the berm at the site is provided in Section 2.1. The hydrogeological characterization of the site is described briefly in Section 2.2, with the full Gartner Lee Ltd. hydrogeological report provided in Appendix A. A discussion regarding the site not being classified as a "potentially sensitive" site is contained within Section 2.3. Substances of potential concern for the SSRA are identified in Section 2.4.

2.1 General Site Description

The OSGC is located at the crest of the Oak Ridges Moraine (ORM), on Lots 4 and 5, Concession 9, in a rural section of the City of Oshawa, Ontario. The OSGC property contains the berm and a clubhouse. The site is surrounded by several small wetlands, rural housing, and various farmlands, including a corn field located on an elevated region to the southwest of the site. Several rural houses are located adjacent to the site, however none of these are with close proximity to the berm. The nearest drinking water well is 625 m from the berm.

In June of 2000, a sound and bullet attenuation berm was constructed at the OSGC using a material called Sound-Sorb. Sound-Sorb, produced by Courtice Auto Wreckers Ltd., is made up of approximately 70 % paper fibre biosolids (PFBs) mixed with 30% mineral soil. The PFBs used in the mixture were provided by Atlantic Packaging Ltd. from two paper recycling plants located in Whitby and Scarborough, and is comprised of approximately 25% paper fibre, 25% clay, and 50% water. The mineral soil used in the Sound-Sorb mixture was taken from a local aggregate pit and was added in order to improve the stability, permeability and sound attenuation of the berm (MOEE, 2002).

The OSGC berm is approximately 90 m long, 20 m wide and 15 m high, and is estimated to contain 27,000 m^3 of material (MOEE, 2002). The berm was constructed in a valley between two treed areas at the south end of the OSGC and was initially covered with 0.15 to 0.30 m of compost material. During a visit to the site in July, 2003, CEI observed that the berm was covered in naturally-occurring vegetation, however, various areas along the sides and top of the berm, particularly on the south side, were no longer covered in vegetation and have experienced shifting, exposing cracks and trenches in the berm material (Figure 2-1). While unvegetated cracks and trenches were noted, the vast majority of the berm remains covered and vegetated. The unvegetated cracks and trenches that were noted were quite small (6 inches across) and as such provide limited opportunity for exposure. Two nonporous drainage pipes exist at the base

of the berm exiting both the north (Figure 2-2) and southwest sides of the berm, respectively. The drainage pipes were put in place in order to allow surface water runoff to flow through and away from the berm, from the elevated fields to the south through to the north of the OSGC.

Figure 2-1 Cracks and trenches in the berm at the OSGC (July 2003)

Figure 2-2 Drainage pipe exiting the north side of the berm at the OSGC (July 2003)

2.2 Hydrogeological Characterization of the Site

A hydrogeological investigation was conducted at the OSGC and the surrounding area by Gartner Lee Ltd. over the fall of 2003 and winter of 2004 (GLL, 2004a; Appendix A). During the investigation, it was determined that the bedrock in the area is covered with more than 100 metres of overburden and that the bedrock groundwater is not typically used as a drinking water source due to the abundance of more shallow aquifers throughout the overburden. The investigation indicated a major groundwater divide just south of the site, at the crest of the ORM from which point the groundwater to the north of the crest (the site of the OSGC) would flow from south to north across the site and would not impact any water body south of the site. In

general, it is expected that the groundwater in the shallower upper sand aquifer follows local topography in the area. The results of an aquifer pump test conducted during the investigation indicated that the shallow and deep groundwater flow systems are isolated from one another in the area. The groundwater is recharged from precipitation and slow infiltration from perched surface water sources. Lack of streams in the area indicate that precipitation infiltrates vertically into the soil and migrates vertically as well as horizontally. This is considered a recharge area of the ORM. The groundwater is sufficiently deep that it does not interact with surface water in the area (GLL, 2004a).

2.3 Sensitive Site Classification

Substances of potential concern (SOPCs) are identified for the SSRA by comparing concentrations in media from the site to MOE criteria contained within the *Guideline for Use at Contaminated Sites in Ontario* (referred to as "the Guideline"; MOEE, 1997). However, it must be determined whether the site would be considered "potentially sensitive" before the appropriate criteria can be identified (*e.g.*, Table A or Table F from MOEE, 1997). The MOE defines a contaminated site as "potentially sensitive" if it meets any of three main criteria (MOEE, 1997). The first criteria related to whether the site is, or affects, any one of the following eight resources:

- A provincial nature reserve established by the Ministry of Natural Resources (MNR),
- A nature reserve zone identified by the MNR;
- A provincially or regionally significant Area of Natural or Scientific Interest (ANSI) designated by the MNR;
- A local environmentally sensitive area identified by a municipality, a conservation authority or other non-provincial body;
- A fish habitat identified by MNR;
- A habitat of vulnerable, threatened or endangered species of birds, wildlife, fish or plants as listed by the MNR;
- A wetland identified as being significant by any planning jurisdiction; or,
- A provincial park as designated by the MNR.

The focus of the assessment includes the Sound-Sorb berm at the OSGC property, which is located on the crest of the Oak Ridges Moraine. Discussions with the Aurora District Office of the MNR (Appendix B) have confirmed that none of the eight conditions listed above apply to the site being assessed. However, the presence of several significant regions including the regionally-significant Enfield Wetlands Area of Natural and Scientific Interest (ANSI), the provincially-significant Enfield Wetland Complex, four Environmentally Sensitive Areas (ESAs) and various Moraine Rare Species can be found in the area surrounding the site.

The Sound-Sorb material used to construct the berm is not expected to move off-site as it is covered in a layer of compost material which is then covered throughout most of the year with either naturally-occurring vegetation, during the spring, summer and fall, or snow, during the winter. As was discussed in Section 2.2 and Appendix A, shallow groundwater from the site does not enter or influence any surface water features in the area (*e.g.*, wetlands, creeks). There remains one outstanding issue, based on MNR information (Appendix B) that should be investigated, regarding the potential for surface runoff from the site to move off-site *via* the headwaters of a tributary of Lake Scugog and the headwaters of two tributaries of East Oshawa Creek, which may be present on the site. During the site visit in July, 2003, the only surface water observed was that shown in Figure 2-2 above. That is, there is no permanent surface water feature adjacent to the berm. However, as mentioned in Section 2.1, two non-porous drainage pipes exist at the base of the berm (Figure 2-2) to allow surface water runoff to flow through and away from the berm, from the elevated fields to the south through to the north of the OSGC. Therefore, it is likely that during some periods of the year (*e.g.*, the spring), surface water is present around the berm. However, the Sound-Sorb material is unlikely to contribute significantly to chemical loading of this water, since leachate from the berm would not enter the pipes in the berm, and surface runoff would be minimized due to the presence of the compost layer and vegetation. Therefore, based on current information, the site is not expected to be classified as "potentially sensitive" based on the first criterion.

The second criterion for a site to be classified as "sensitive" relates to the depth of overburden over bedrock. The Guideline states that a site is sensitive if "site conditions are such that there are less than two metres of overburden and soil overlying the bedrock in the contaminated areas of the site" (MOEE, 1997). During the hydrogeological investigation, it was determined that, according to MOE well records, the bedrock in the area is covered by more than 100 metres of overburden (GLL, 2004a). Therefore, the site would not be considered sensitive according to this criterion.

The final criterion relates to the pH of the soil at the site. A site may be considered sensitive if the soil pH falls outside the range of pH 5 to 9 for surface soils, or pH 5 to 11 for subsurface soils (greater than 1.5 m depth). The pH of the Sound-Sorb material used to construct the berm ranges between 7.7 and 8.5 while the background soil sample collected by the MOE in November of 2001 on the north side of Coates Road had a pH of 7.2. The pH of both the Sound-Sorb berm material as well as the background soils fall within the range specified by the MOE. Therefore, the site would not be considered "sensitive" according to this criterion.

In summary, based on our current understanding of the conditions at the OSGC, the site does not satisfy the criteria for a "potentially sensitive" site, as defined by the MOE (MOEE, 1997). Therefore, SOPCs will be identified using the Table A Generic Criteria (MOEE, 1997).

2.4 Selection of SOPCs

The sampling data described below were used to identify SOPCs for the berm material (Section 2.4.1), berm leachate (Section 2.4.2), local drinking water wells (Section 2.4.3) and local groundwater (Section 2.4.4). Tables containing all of the site data used for the selection of SOPCs are included in Appendix C.

2.4.1 Sound-Sorb Berm

Sampling of the OSGC Sound-Sorb berm material was conducted on two separate occasions, initially by Gartner Lee Limited (GLL, 2001) in June of 2001, and again by the MOE (MOEE, 2002) in November of 2001.

In June of 2001, GLL was retained by the Health Department of the Regional Municipality of Durham to conduct sampling and chemical analysis of the Sound-Sorb berm material at the OSGC. Ten test pits were dug within the south side of the berm to depths of approximately 1.5 m. The compost material coating the berm was removed before the test pits were dug and five samples of the Sound-Sorb material were collected from both the eastern and western halves along the south side of the berm. The five samples collected from each half of the berm were mixed together to form two composite samples which were then analysed for numerous substances including metals, BTEX (benzene, toluene, ethylbenzene, and xylenes), and various bacteria. Petroleum hydrocarbons were not measured during this analysis (GLL, 2001).

In November of 2001, the MOE conducted sampling of the berm at the OSGC. Three samples were collected from a core on the north side of the berm with a total depth of approximately 120 cm followed by two additional samples from a second core collected at a point closer to the base of the berm with a total depth of approximately 90 cm. A sample of undisturbed soil was collected from the north side of Coates Road, directly opposite the entrance to the OSGC, to a total depth of approximately 80 cm, to represent the natural soil surrounding the site. The background soil sample was assumed to be similar to the soil used in the mixture with the paper fibre biosolids to produce the Sound-Sorb material during the construction of the berm at the OSGC.

The samples collected from the berm and from the Coates Road location were analysed for numerous compounds including a full suite of metals, various bacteria, volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), dioxins and furans, chlorophenols, nonylphenol ethoxylates, petroleum hydrocarbons and the acrylamide monomer.

The MOE conducted a similar analysis on samples of the paper fibre biosolids sludge produced by Atlantic Packaging's Whitby Plant (MOEE, 2002). This material was being stored in a bunker at the plant before it would be either applied to agricultural lands or used to produce Sound-Sorb material. The analyses indicated that the fresh PFBs met all guideline levels in the *Guideline for the Utilization of Biosolids and Other Wastes on Agricultural Land* (OMAFRA and MOE, 1996). These results will not be evaluated specifically in the SSRA, but were reviewed and considered as supporting data.

The results of the berm sample analyses from both GLL and the MOE, as well as the results of the background soil sample analysis by MOE, were reviewed and evaluated in the current assessment. The results were screened initially against the MOE Table A generic criteria for coarse-grained soils and residential/parkland use in a potable groundwater situation where criteria were available (MOEE, 1997). Results were screened using the MOE Table F background soil concentrations (all other land uses) and Ontario Typical Range (OTR) values (MOEE, 1993) where Table A criteria were not available.

Total petroleum hydrocarbons were detected in the berm at a level greater than the Table A criteria. All other compounds analysed in the berm and background samples were below the MOE Table A generic criteria, where criteria were available (Table 2-1).

Screening of the remaining substances (without Table A criteria) with the MOE Table F background soil concentrations and OTR values was conducted since no health based standards are available for these substances. This screening revealed exceedances of one or more samples for calcium, strontium and water extractable chloride (Table 2-1).

It should be noted that the review of the original lab data for the June (2001) analysis indicated that core concentration for barium were incorrectly reported as arsenic. Correction of this error, resulting in the following modifications to the assessment:

- Core barium concentrations from the June 2001 analysis were less than the relevant MOE criteria; and,
- Arsenic was not analyzed as part of the June 2001 sampling program; however, analyses conducted in November, 2001 revealed that all measured levels of arsenic were less than the relevant MOE criteria.

Table 2-1 OSGC Berm and Background Soil Samples in Exceedance of the MOE Table A and Background Criteria

SOPC	MOE Table A Criteria (µg/g)	MOE Background[a] Criteria (µg/g)	Concentration in Sample (µg/g)	Depth (m)
Calcium	NA	55,000[b]	100,000	0 - 0.1
			61,000	0.45 – 0.65
			60,000	0.80 – 1.0
			58,000	0 – 0.10
			64,000	0.24
			80,800	Composite
			83,200	Composite
Chloride	NA	330	540[c]	0.45 – 0.65
			880[c]	0.80 – 1.0
			840[c]	0.24
Strontium	NA	64[b]	118	0 – 0.10
			74	0 – 0.10
			95	0.24
			74.5	Composite
			97.6	Composite
Total Petroleum Hydrocarbons	1,000 100	NA	3,400[d]	0.80 – 1.0

[a] Background criteria are from Table F unless indicated

[b] OTR_{98} (MOEE, 1993) used due to lack of other available criteria.

[c] Reported concentrations are for water extractable chloride.

[d] Berm sample collected in June 2001 (GLL, 2001) and November of 2001 (MOEE, 2002).

NA Indicates no criterion available

Calcium was detected at concentrations greater than the typical background range for Ontario at varying depths within the berm; however, the maximum detected concentration of calcium was less than twice the typical background range. Calcium will not be considered further in the SSRA because it is an essential mineral nutrient required for human health.

Chloride was detected at concentrations of between 1.5 and 3 times greater than the typical background range for Ontario, at varying depths within the berm. Chloride is a common anion which is ubiquitous in the environment. It was not retained as an SOPC because it does not present a health concern.

Other sources of risk-based screening criteria for strontium were consulted because MOE does not have a Table A or F criterion for this element. The U.S. EPA Region 9 has derived a Preliminary Remediation Goal (PRG) of 47,000 µg/g for strontium in residential soils (U.S. EPA Region 9, 2002). Using this value divided by 5 (to account for other sources of exposure) as a

screening criterion, the levels of strontium in the berm material are not expected to result in any adverse effects to human health as the maximum concentration detected in the berm was 118 µg/g.

Acrylamide monomer was detected in one berm sample collected from the surficial layer of the berm (0-10 cm) by the MOE in November, 2001. No Table A or Table F criteria exist for acrylamide monomer; however, the U.S. EPA Region 9 has derived a PRG of 0.11 µg/g for acrylamide in residential soil. The concentration of acrylamide monomer detected in the berm of 0.36 µg/g exceeds the U.S. EPA Region 9 PRG for residential soil. Therefore this substance will be carried forward in the SSRA.

Several substances that were measured in the berm samples do not have Table A, Table F (OTR) or U.S. EPA Region 9 criteria available, including cyanide (total), nitrogen (total), phosphorus (total), and sulphate (water extractable) (Appendix C).

Total cyanide was detected at varying depths within the berm at concentrations ranging between 7.6 and 10 µg/g; however, no screening criterion exists for total cyanide in soil. Free cyanide was detected in the berm but at concentrations well below the MOE Table A criterion of 100 µg/g. Since the maximum total cyanide concentration detected in the berm is 10 times below the MOE Table A criterion for free cyanide, it is not expected to adversely impact human health or the environment, and therefore will not be carried forward in the SSRA.

Total nitrogen, phosphorus and sulphate were all detected at varying depths within the berm; however, these substances are considered to be common nutrients that are not typically evaluated in risk assessments. Therefore, these substances were not evaluated further in the SSRA.

Analyses for microorganisms in berm samples were conducted by GLL (2001), MOE (MOEE, 2002) and Sporometrics (2003). MOE analysed for *E. coli*, total coliform, fecal streptococci and *Pseudomonas aeruginosa* whereas GLL analysed only for *E. coli* and total coliform. Neither fecal streptococci nor *P. aeruginosa* were detected in the four berm samples tested by MOE (MOE, 2001). *E. coli* was detected in one of four samples by MOE at 100 cfu/g, whereas it was not detected in the samples taken by GLL. The level of 100 cfu/g is less than the U.S. EPA guideline of 1000 cfu/g for Class A biosolids (MOEE, 2002). Total coliforms were detected in the berm by both MOE and GLL, at levels ranging from 9,700 cfu/g to 10,000 cfu/g. Sporometrics (2003) conducted the most comprehensive sampling and analysis, and detected a number of bacteria and fungi from within the OSGC berm.

In summary, based on the analysis of the berm samples to date, TPH, acrylamide monomer and, bacteria and fungi within the berm will be carried forward as SOPCs for evaluation in the SSRA. Bacteria and fungi will be evaluated solely as a human health concern.

2.4.2 Sound-Sorb Berm Leachate

Screening for SOPCs in berm leachate samples was conducted using the Ontario Regulation 347 Schedule 4 Leachate Quality Criteria, where available, for any sample detected above the detection limit or EQL used in analysis. The Regulation 347 Criteria were considered appropriate for this purpose since they provide an indication of the likelihood that a contaminant will migrate from the berm. If a contaminants was not leachable according to Regulation 347 it was assumed that this substance would not likely leach from the berm. Any SOPC detected at levels exceeding the leachate criteria were then compared with MOE Table A generic criteria for potable groundwater in order to be protective of human health. It was assumed that if pure leachate met the drinking water criteria (Table A generic) than an insufficient amount of the substance was leachable to impact groundwater resources in the area. See Appendix C for complete data set.

Sound-Sorb berm samples collected by GLL from both the eastern and western halves of the south side of the berm were divided for solid and acid leachate analysis in order to evaluate natural leaching conditions (GLL, 2001). The results of the screening indicate that few of the compounds analysed in the samples, including various metals, BTEX, and nonylphenol ethoxylates, were detected above their respective detection limits. Barium was detected above the detection limit in both the eastern and western composite samples; however, the levels detected were well below the leachate quality criteria for barium of 100 mg/L. Low concentrations of copper and zinc, for which no leachate criteria exist, were also detected and may be present in any leachate formed *in situ*. It should be noted that the concentrations of both copper and zinc detected in the leachate analysis were well below their respective MOE Table A generic criteria for potable groundwater.

In November of 2004, GLL collected additional Sound-Sorb berm material from five new boreholes drilled in the OSGC berm for Toxicity Leachate Extraction Procedure (TCLP) analysis (GLL, 2004b). The results of the analysis indicated four substances, of the more than 90 substances analysed, were detected above the Estimated Quantitation Limit (EQL); these were barium, boron, fluoride and three cresol isomers (m-, p-, and o-). The levels of these four substances were between 3 and 4 orders of magnitude lower than their respective Schedule 4 Leachate Quality Criteria. The levels of barium and boron detected in the berm material were also below their respective MOE Table A generic criteria for potable groundwater (see Table 2-2). Five substances tested in the TCLP analysis do not have Leachate Quality Criteria

(de-ethylated atrazine, alachlor, prometryne, N-nitrosodimethylamine, and 2,4-dichlorophenol); however, none of these five substances were detected at levels greater than the EQL and therefore were not considered further in the assessment. TCLP analysis for dioxins and furans (TEQ) indicated concentrations (maximum = 3.33 pg/L) were well below the Leachate Quality Criteria of 1,500 pg/L.

Table 2-2 SOPC Concentrations Detected in Sound-Sorb Berm Leachate Analysis (TCLP)

SOPC	Sample Concentration Range (mg/L)	O. Reg 347 Schedule 4 Leachate Quality Criteria (mg/L)	MOE Table A criteria (mg/L)
Barium	0.4 – 0.7	100	1
Boron	0.2 – 0.3	500	5
Copper	0.007[a]	NA	0.023
m-Cresol & p-Cresol	0.0116 – 0.0252	200[b]	NA
o-Cresol	0.0023[c]	200	NA
Fluoride	0.2 – 1.2	150	NA
Zinc	0.10 – 0.18	NA	1.1

[a] Indicates only one sample was analysed.

[b] Indicates leachate criteria exists for each isomer.

[c] Indicates only one sample was detected above the EQL.

NA Indicates no criterion available.

Based on these analyses of leachate from the berm, no additional SOPCs would be identified.

2.4.3 Local Drinking Water Wells

In September of 2003, both the MOE and the Durham Regional Health Department conducted separate (individual) sampling and analyses of 6 local drinking water wells surrounding the OSGC for the presence of polychlorinated aromatic hydrocarbons (PAHs). The results of both analyses indicate there were no PAHs detected in any of the 6 drinking water wells sampled. All detection limits were less than or equal to Table A criteria. This result was not unexpected given the slow mobility of PAHs in groundwater.

2.4.4 Local Groundwater

Sampling of the groundwater at the OSGC and in the surrounding area was conducted by the MOE on four separate occasions. The MOE collected samples of the groundwater from monitoring wells located on the OSGC property (MW1 to MW4), south of the OSGC berm (MW5), at the Harmony Road Compost Site (MW6 to MW9 and MW14) and at the Ambrose Aggregate Pit (MW10 to MW13) (Figure 2-3). Each sweep of groundwater sampling was analysed for over 170 compounds and bacteria including metals, VOCs, SVOCs, PAHs, numerous pesticides, petroleum hydrocarbons, BTEX compounds, acrylamide, and *E. coli* (Appendix C).

The process of screening the results of the groundwater sampling events involved multiple steps. As a first step, the groundwater sampling results were compared to the MOE Table A generic criteria for potable groundwater in a residential/parkland scenario from the *Guideline for Use at Contaminated Sites in Ontario* (MOEE, 1997). The second screening step was a comparison with the Ontario Drinking Water Quality Standards (ODWQS), where values were available (MOE, 2003a). In cases where neither a Table A criterion nor an ODWQS value existed for a certain parameter, the groundwater results were compared to criteria from other jurisdictions such as the U.S. EPA Region 9 PRGs for tap water (divided by a factor of 5 for non-carcinogenic compounds) to account for other sources of exposure (U.S. EPA Region 9, 2002).

The first suite of groundwater samples was collected by the MOE in March of 2003 (Sweep 1). During this sampling event, MW9 was dry and MW14 was under repair, therefore, no samples were collected from these wells at this time. Additionally, the sample collected from MW3 was taken in December, 2002 rather than in March, 2003; however, it has been included in the evaluation of groundwater samples despite the fewer number of compounds that were analysed for in this sample. The Sweep 1 samples that were collected were not decanted or filtered to separate any suspended sediment from the groundwater before being analysed; the samples were collected before disinfection of the monitoring wells had been conducted.

The second suite of groundwater samples, collected in May of 2003 (Sweep 2), did not include sampling of MW9 or MW14 for the same reasons as discussed above. The Sweep 2 groundwater samples were collected after the monitoring wells had undergone disinfection. A third and fourth suite of groundwater samples, collected in October of 2003 (Sweep 3) and February of 2004 (Sweep 4), also did not include sampling of MW9 or MW14. The groundwater samples collected for PAH analysis during Sweep 3 were filtered to remove sediment from the samples.

The results of the first screening of the groundwater data revealed that six SOPCs in Sweep 1, nine SOPCs in Sweep 2, two SOPCs in Sweep 3, and one SOPC in Sweep 4 were detected at levels that exceeded the MOE Table A potable groundwater criteria. Of the SOPCs that exceeded the Table A criteria in Sweeps 1 and 2, seven of them were PAHs. Elevated concentrations of benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, and indeno(1,2,3-cd)pyrene were detected in MW1 in both sweeps of groundwater data and were also detected at elevated levels in MW7, along with chrysene, in the Sweep 2 groundwater data. Benzo(a)pyrene was also detected at an elevated concentration in MW2 in Sweep 1. In addition, benzo(e)pyrene was detected in Sweeps 1 and 2 but there are no criteria against which to compare these concentrations. No PAHs were detected in Sweeps 3 or 4, when the samples were filtered to remove sediment. PAHs were not retained as SOPCs because: no PAHs were detected in Sweeps 3 or 4; PAHs were not detected in drinking water wells (see Section 2.4.3); and, the MOE is confident that PAHs are not originating from the berm (Neary, 2003).

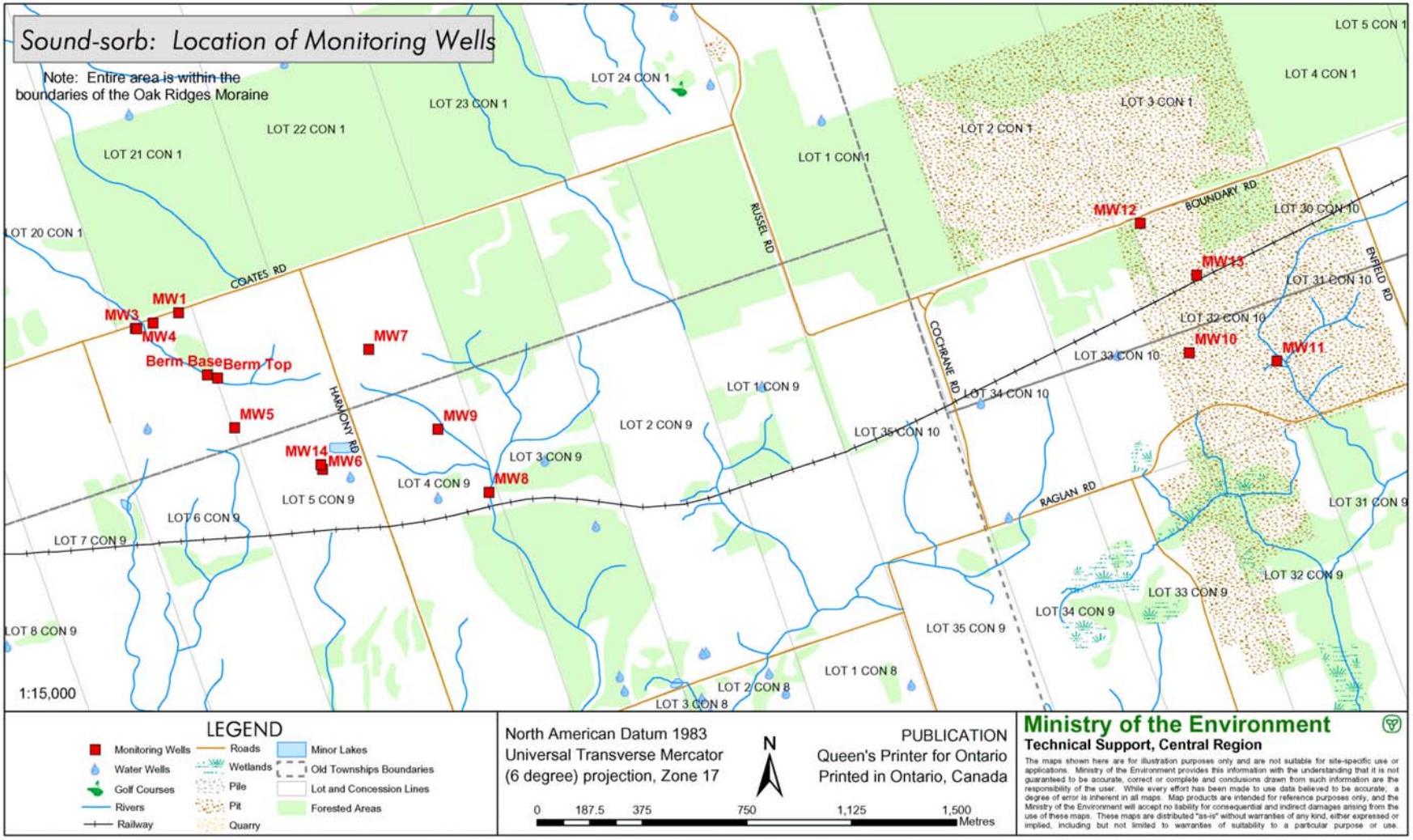

Figure 2-3 Monitoring well locations around the OSGC

Chloroform and sodium were detected at concentrations that exceeded the Table A criteria in Sweep 2 at MW5 and MW4, respectively. Levels of chloroform that exceeded the Table A criterion were also detected during Sweep 3 at MW4 and MW5 and in Sweep 4 at MW4. One exceedance of the Table A criterion for total PCBs was detected at MW12; however, at the level detected, the concentration of total PCBs was well below the ODWQS. Table 2-3 provides a summary of the SOPCs that exceeded the MOE Table A potable groundwater criteria.

Table 2-3 SOPC Concentrations in Groundwater in Exceedance of the MOE Table A Potable Groundwater Criteria

SOPC	Monitoring Well Location	Sample Concentration (µg/L)	MOE Table A criteria (µg/L)
SWEEP 1			
Benzo(a)pyrene	MW1 MW2	0.440 0.046	0.010
Benzo(a)anthracene	MW1	0.380	0.200
Benzo(b)fluoranthene	MW1	0.410	0.200
Benzo(k)fluoranthene	MW1	0.360	0.200
Benzo(g,h,i)perylene	MW1	0.320	0.200
Indeno(1,2,3-cd)pyrene	MW1	0.480	0.200
SWEEP 2			
Benzo(a)pyrene	MW1 MW7	0.620 0.520	0.010
Benzo(a)anthracene	MW1 MW7	0.550 0.370	0.200
Benzo(b)fluoranthene	MW1 MW7	0.700 0.520	0.200
Benzo(k)fluoranthene	MW1 MW7	0.620 0.420	0.200
Benzo(g,h,i)perylene	MW1 MW7	0.270 0.280	0.200
Indeno(1,2,3-cd)pyrene	MW1 MW7	0.840 0.450	0.200
Chloroform	MW4 MW5	<260 7.9	5.0
Chrysene	MW1 MW7	0.620 0.530	0.500
Sodium	MW4	923,000	200,000
SWEEP 3			
Chloroform	MW4 MW5	44 8.6	5.0
Total PCBs	MW12	0.226	0.200
SWEEP 4			
Chloroform	MW4	88	5.0

Note: MW1 – MW4 are located on OSGC site; MW5 south of berm; MW6 – MW8 at the Harmony Road Compost Site; and MW10 – MW13 at the Ambrose Aggregate Pit.

Total PCBs were detected at a concentration slightly greater than the MOE Table A criterion at MW12; however, this SOPC is not expected to have originated from the berm as MW12 is situated at the Ambrose Aggregate Pit which is located on the south side of groundwater divide (GLL, 2004a). In addition, the level of PCBs detected was less than the ODWQS for PCBs (3 ug/L), indicating that that the levels detected do not present an unacceptable human health risk (Safe Drinking Water Act, 2002).

The elevated level of sodium detected at MW4 in Sweep 2 is anticipated to result from the presence of residual sodium hypochlorite (bleach) used to disinfect the well before sampling in Sweep 2. The levels of sodium at MW4 during Sweeps 1, 3 and 4 were in the normal range for groundwater in the area (MOE, 2004) as disinfection had not occurred before sampling during either Sweep 1, 3 or 4. Sodium also was not detected at elevated levels in Sweep 3 or Sweep 4. Therefore, sodium was not retained as an SOPC for the SSRA.

The chloroform at MW4 in Sweeps 2, 3 and 4 also is anticipated to result from the disinfection of the well prior to sampling in Sweep 2. Chloroform is a known byproduct of disinfection from the use of bleach and is formed by the reaction of free chlorine with dissolved organic matter in water. During Sweep 1, chloroform was not detected, and the detection limit was 0.2 µg/L. In Sweep 2, the elevated concentration of chloroform necessitated the dilution of the sample for analytical purposes, which resulted in high detection limits. In Sweeps 3 and 4, the concentrations of chloroform at MW4 (44 µg/L and 88 µg/L, respectively) were lower than in Sweep 2; however, due to these elevated concentrations, the samples required dilution prior to analysis resulting in elevated detection limits for all VOCs analysed at MW4. Regardless, chloroform concentrations in Sweep 3 are less than the ODWQS for trihalomethanes (THM, which also include bromodichloromethane, chlorodibromomethane and bromoform, all of which were at non-detect levels) of 100 µg/L. In Sweep 4, the elevated detection limits for all VOCs at MW4 result in a total THM concentration of 113.8 µg/L; however, chloroform was the sole THM detected in the analysis. For these reasons, chloroform was not retained as a SOPC. However, it is recommended that MW4 continue to be monitored with particular attention paid to chloroform concentrations in the groundwater.

The second screening of the groundwater data, using ODWQS values, also revealed concentrations of nitrogen (nitrate + nitrite) above the standard of 10,000 µg/L at more than one monitoring well in the first 3 groundwater sweeps (Table 2-4). Nitrogen (nitrite) was also detected above the ODWQS at MW4 in Sweep 2.

Table 2-4 SOPC Concentrations in Groundwater in Exceedance of the ODWQS

OPC	Monitoring Well Location	Sample Concentration (mg/L)	ODWQS criteria (mg/L)
SWEEP 1			
Nitrogen (nitrate + nitrite)	MW7 MW13	30.6 19.6	10.0
SWEEP 2			
Nitrogen (nitrate + nitrite)	MW6 MW7	38.1 10.3	10.0
Nitrogen (nitrite)	MW4	1.59	1.0
SWEEP 3			
Nitrogen (nitrate + nitrite)	MW6 MW7	14.5 46.2	10.0

Note: MW1 – MW4 are located on OSGC site; MW5 south of berm; MW6 – MW8 at the Harmony Road Compost Site; and MW10 – MW13 at the Ambrose Aggregate Pit.

The elevated levels of nitrogen detected above the ODWQS at various monitoring wells in the area are not unexpected since the OSGC is surrounded by farmland which may undergo fertilizer treatments including various nitrogen compounds which can leach into the groundwater. In addition, two of the four monitoring wells in which nitrogen, as nitrate plus nitrite, were detected (MW6, MW7) are located at the Harmony Road Compost Site, which may be a source of elevated nitrogen levels. Additionally, MW13 is at the Ambrose Aggregate Pit. Only MW4 is located at the OSGC, and nitrogen levels were only 1.6 times the ODWQS in Sweep 2. Nitrogen was not detected at MW4 in subsequent sampling events (Sweeps 3 and 4). Nitrogen, as nitrate or nitrite, was not retained as an SOPC for these reasons.

Further review of the groundwater data indicated that, in a few instances, the method detection limit (MDL) used in the analysis of certain SOPCs was greater than the MDL recommended by the MOE for use in groundwater analyses (MOEE, 1996a). For the analysis of 2,4-dichlorophenol, the MDL achieved by the laboratory (2.0 µg/L) was well above the MOE-recommended MDL of 0.2 µg/L as well as the Table A criteria of 0.3 µg/L. However, 2,4-dichlorophenol was never detected above the MDL of 2.0 µg/L at any of the monitoring locations and therefore, never exceeded the ODWQS criterion of 900 µg/L (0.9 mg/L). Therefore, this compound was not evaluated in the SSRA.

Also of note in Sweep 2, the analysis of 1,4-diethylbenzene and 1,3-diethylbenzene found that these compounds, they were never detected above the MDL used (0.6 µg/L), and therefore, these compounds were not evaluated in the current SSRA.

In addition, there were no criteria available for 45 of the compounds that were analysed for in the groundwater samples. Of these 45 compounds, most (32 compounds) were never detected above the MDL used in the analysis and, based on this, were not carried forward for evaluation in the SSRA. It is noted, however, that MW4 in Sweeps 2, 3 and 4 had MDLs for several VOCs which exceeded Table A criteria (see Table C5.C6, and C7).

Of the remaining compounds without available groundwater criteria, 13 compounds were detected at one or more monitoring well locations in at least one of the sweeps of groundwater samples. Of these 13 compounds, perylene was detected at various locations in Sweep 1 and Sweep 2 but not at levels greater than the MOE MDL, and therefore will not be evaluated as a SOPC. Calcium and magnesium were detected in all groundwater samples but are considered components of water hardness, and therefore will not be considered further in the SSRA.

Chloride, manganese, sulphate and sulphide were all detected above their respective MOE MDLs in each of the four sweeps of groundwater samples and, for lack of other available screening criteria, were compared to the Guidelines for Canadian Drinking Water Quality (Health Canada, 2003). The criteria derived by Health Canada for these four substances are aesthetic objectives based on taste and odour thresholds (derived when these thresholds for a particular substance are less than the maximum acceptable concentrations). Sulphate and chloride concentrations in groundwater were all below their respective aesthetic objectives of 500 mg/L and 250 mg/L, with the exception of chloride at MW4 in Sweep 2 (1,340 mg/L). It has been suggested that the elevated level of chloride at MW4 was likely caused by inadequate well purging following disinfection of the well with sodium hypochlorite (bleach) (MOE, 2004). Manganese slightly exceeded the aesthetic objective of 0.05 mg/L in Sweep 1 at MW4 (0.0794 mg/L) and in Sweep 4 at MW7 (0.100 mg/L) and MW8 (0.059 mg/L). Sulphide slightly exceeded the aesthetic objective of 0.05 mg/L at one monitoring location in Sweep 1. However, the guideline values for manganese and sulphide were only slightly exceeded, and as the guideline values are aesthetic objectives (less than the health-based values), these levels are not expected to adversely impact human health or the environment. Based on the discussion above, chloride, manganese, sulphate and sulphide will not be considered further in the SSRA.

Potassium was detected in all four sweeps of groundwater sampling with a maximum concentration of 1.8 mg/L detected during Sweep 2 sampling. According to a report on groundwater resources published by the British Columbia Ministry of Water, Land and Air Protection, potassium is considered to be a secondary mineral constituent of most groundwater with natural levels ranging from 0.01 to 10.0 mg/L (BC MWLAP, 2001). The levels of potassium in the groundwater at the OSGC and surrounding areas are well within the normal range and therefore, will not be considered further in the current assessment.

Pyrethrin 1, pyrethrin 2 and piperonyl butoxide were measured in groundwater and have no available screening criteria. These 3 substances are considered "pyrethrins", and were present below the detection limit (0.1 µg/L) in Sweep 1 and Sweep 4 and were not measured in Sweep 2 due to analytical laboratory problems (MOE, 2004). Sweep 3 results reported concentrations of these 3 substances detected at five of the monitoring wells sampled (MW1, MW2, MW3, MW4 and MW7) at a concentration equal to the detection limit (*i.e.*, 0.1 µg/L). These insecticides are used commonly in residential and agricultural settings, for control of insects and mites (*e.g.*, on domestic and farm animals, vegetables, field crops, house plants) (Tomlin, 1994). They also have low mammalian toxicity and are not phytotoxic (Tomlin, 1994). Therefore, because concentrations were at the detection limit, and these chemicals have low mammalian- and phyto-toxicity, they were not included as SOPCs in the SSRA.

Titanium was detected at concentrations greater than the MOE MDL (2.5 µg/L) at more than one sampling location. The highest concentrations detected were approximately twice the detection limit, at MW6 (5.2 µg/L in Sweep 1) and MW8 (5.7 µg/L and 4.9 µg/L for Sweeps 1 and 2, respectively). Titanium was detected at MW4 (near the OSGC) at 4.7 µg/L in Sweep 1 and 2.7 µg/L in Sweep 3 (it was not detected above 2.5 µg/L in Sweep 2). It also was detected at MW13 at 2.8 µg/L in Sweep 3. The levels detected were well below the U.S. EPA Region 9 PRG of 150,000 µg/L for tap water, as well as the source allocation PRG of 30,000 µg/L (PRG divided by a factor of 5 to account for other sources of titanium) (U.S. EPA Region 9, 2004). Therefore, titanium was not retained as a SOPC for the SSRA.

Acrylamide was analysed for in each sweep of groundwater samples and was not detected above the detection limit (0.3 µg/L) in any of the samples. This detection limit exceeds the U.S. EPA Region 9 PRG of 0.015 µg/L for acrylamide in drinking water and the World Health Organization recommended drinking water limit (0.04 µg/L). Therefore, acrylamide was retained as an SOPC. It is noted that for sweep 4, MOE refined their analytical methods to ensure detection limits in line with the such as the 0.04 µg/L drinking water limit recommended by the World Health Organization. Sweep 4 results were all less than the MDL of 0.04 µg/L.

Total coliform and *E. coli* also were analysed for in groundwater samples, but were not detected in any Sweep (Appendix C). However, prior to the analysis in Sweep 1 (as presented in Appendix C), samples were taken from wells and *E. coli* was detected. The presence of *E. coli* was thought to result from contamination during drilling activities (MOE, 2003b). Therefore, the wells were disinfected, which is consistent with well installation best practices. Sampling after disinfection revealed no *E. coli* in the wells. Even if *E. coli* were present in groundwater at the OSGC, GLL (2004a) and Stantec (2004) conclude that the time of travel required for *E. coli* (or *Aspergillus fumigatus* or other pathogenic fungal species associated with the OSGC) in groundwater to reach the nearest domestic drinking water well would far exceed the maximum

survival time for these organisms in groundwater. Therefore, no bacteria or fungi were retained as SOPCs in groundwater for the SSRA.

In summary, the following SOPCs were selected for evaluation in the current SSRA:

SOPCs in the OSGC berm:

- acrylamide monomer
- total petroleum hydrocarbons (TPH)
- bacteria and fungi

As discussed earlier, the current assessment did not evaluate any SOPCs in leachate from the berm or in the local drinking water as there were no SOPCs detected at levels that exceeded the appropriate screening criteria for these environmental media.

3.0 HUMAN HEALTH RISK ASSESSMENT

The fundamental purpose of a human health risk assessment (HHRA) is to estimate whether people working, living or visiting in a given location are being exposed, or will be exposed to concentrations of substances that have the potential to result in adverse health effects. It requires consideration of the toxic properties of the substances, the presence of receptors, and the existence of exposure pathways to the receptors. When all three factors are present (*i.e.*, chemicals, receptors and exposure pathways), there is a potential for adverse health effects to occur if exposures to the substances are elevated above levels associated with toxic effects.

The human health risk assessment follows the protocol and principles of the Ontario Ministry of the Environment's SSRA process as outlined in the *Guidance on Site Specific Risk Assessment for Use at Contaminated Sites in Ontario* (MOEE, 1996b). The human health risk assessment consists of the following four main steps (Figure 3-1): Problem Formulation; Exposure Assessment; Hazard Assessment; and Risk Characterization. A brief description of each of these steps is provided below.

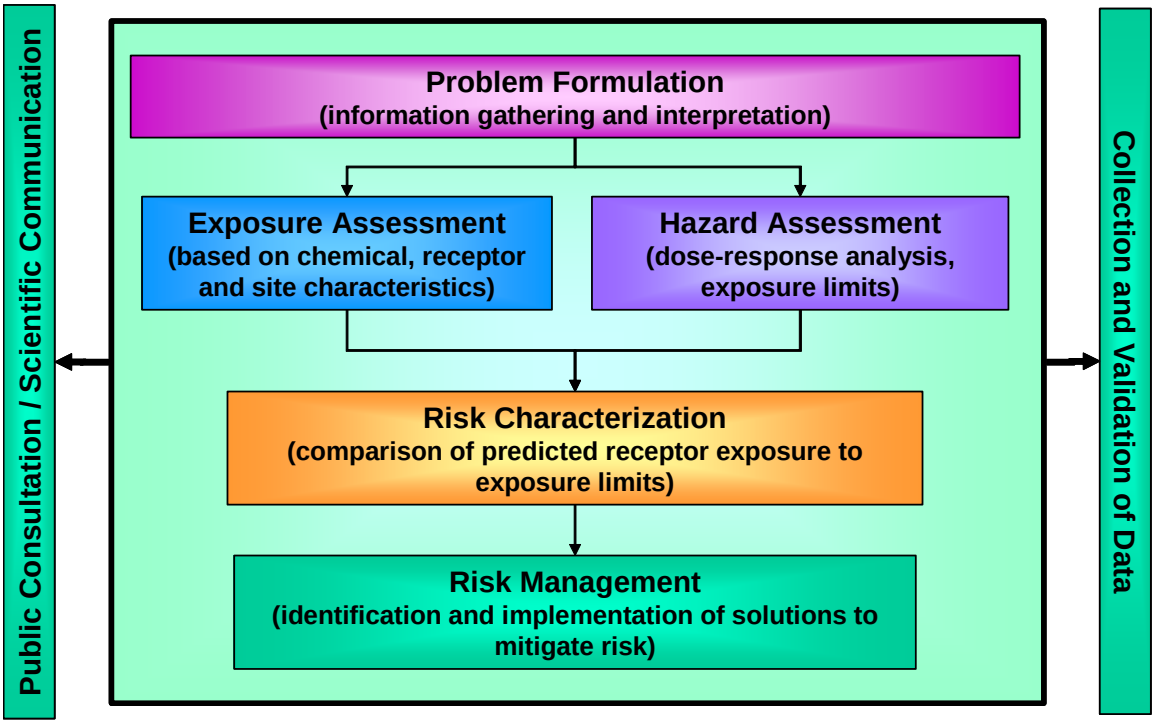

Figure 3-1 The basic steps in a human health risk assessment

3.1 Problem Formulation

Problem formulation acts as an information-gathering and interpretation stage, which is conducted to plan and focus the approach of the risk assessment on critical areas of concern for the site being evaluated. It is noted that the Sound-Sorb berm is the focus of this SSRA, not the entire OSGC site. Data and reports on the properties of Sound-Sorb, as well as studies pertaining to the potential impacts associated with this product at the OSGC, were obtained from the MOE.

The key tasks requiring evaluation within the problem formulation phase include receptor characterization and identification of exposure pathways. Receptor characterization identifies "receptors of concern", which include those with the greatest probability of exposure to substances from the berm and those that have the greatest sensitivity to these substances. The identification of exposure pathways takes into account chemical-specific parameters, such as solubility and volatility, characteristics of the berm, such as physical geography, geology and hydrogeology, as well as the physiology and behaviour of the receptors.

3.1.1 Receptor Characterization

A human receptor is a hypothetical person (*e.g.*, infant, toddler, child, adolescent, adult) who resides or works in the area being investigated and is, or could potentially be, exposed to the substances identified as being of potential concern. General physical and behavioural characteristics specific to the receptor type (*e.g.*, body weight, breathing rate, food consumption rate, *etc*.) are used to determine the amount of exposure received by each receptor. Due to differences in these characteristics between children and adults and between males and females, the exposures received by a female child, a male child, a female adult or a male adult may be different in some circumstances. Consequently, the potential risks associated with SOPCs will differ depending on the receptor chosen for evaluation.

It is important that the assessment is sufficiently comprehensive to ensure that overall risks have been adequately addressed. However, it is not feasible to consider all human receptors that may be potentially exposed to SOPCs from the berm. Accordingly, it is important to select receptors that will be at greatest potential risk. These will be receptors with the greatest probability of exposure to SOPCs from the berm and those that have the greatest sensitivity to these SOPCs.

Typically, females experience higher exposures than males, when considered on a per body weight basis. For this reason, females are considered to be more sensitive than males and are often selected as an appropriate receptor for assessment. Additionally, children are typically more sensitive to exposures to substances than adults and can experience different levels of

exposure through different activities they might experience. Based on these factors, a female child often is selected as a receptor.

For the current SSRA, four main types of human receptors may be exposed to SOPCs originating from the berm:

1) Off-site residents;
2) Workers at the OSGC;
3) Members of or visitors to the OSGC; and,
4) Trespassers.

Either males or females could be present as nearby residents, workers or members of the OSGC, or trespassers. Therefore, the human receptors selected for evaluation include the female child (to address non-carcinogen SOPCs) and a life-time (or composite) female receptor (to address carcinogenic SOPCs) to evaluate the potential risk to an individual exposed throughout all their life stages (infant, preschool child, child, adolescent, and adult).

3.1.2 Exposure Pathway Screening

Humans may come into contact with substances in their environment in a variety of ways, depending on their daily activities and the ways in which they utilize local resources (*e.g.*, land, water bodies). There are three major exposure routes through which substances can enter the body: inhalation, ingestion and dermal absorption through the skin. There can only be a health risk when there is a complete link from a substance (*e.g.*, metal, PAH, bacteria), through an environmental medium (*e.g.*, air, groundwater, soil) to a person (*e.g.*, inhalation of volatile compounds, ingestion of substances in soil or groundwater). When all three factors are present (*i.e.*, substance, receptor and exposure route), there is a potential for adverse effects to occur if exposures are elevated above acceptable levels (see Figure 3-2).

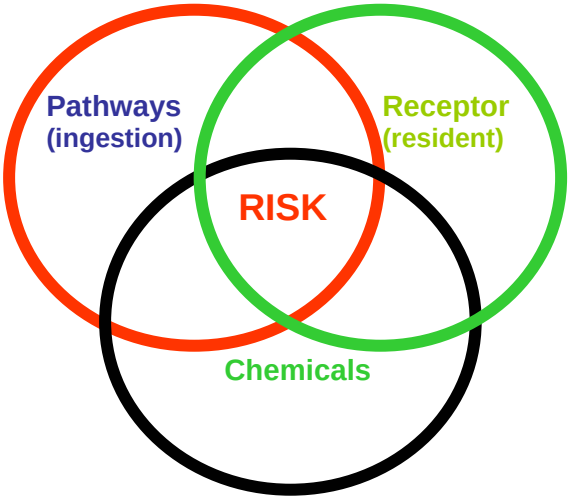

Figure 3-2 Factors Required for a Risk of Adverse Effects

If there is no possible exposure to a chemical, regardless of its toxic potency or environmental concentration, there would be no potential for the development of adverse health effects. That is, without all three factors, there can be no risk (see Figure 3-3).

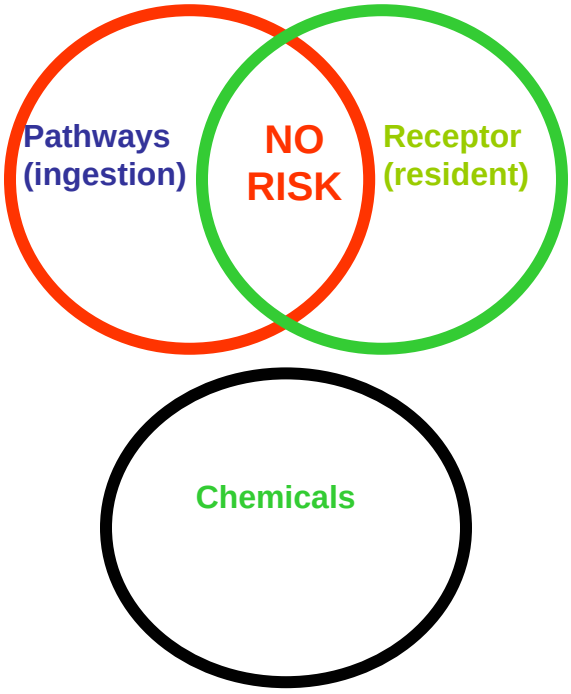

Figure 3-3 Without all three factors, there can be no risk

The contaminated environmental media of concern to human health were limited to the air, groundwater, and the Sound-Sorb material used to construct the berm. The berm is currently covered in a layer of compost material which, in turn, is covered throughout most of the year by either vegetation (in the spring and summer months) or snow (during the winter) thereby limiting an individual's potential for exposure to the Sound-Sorb material. The potential for compounds to leach from the berm into the groundwater was also considered for determination of potential exposure pathways of concern (Figure 3-4).

Given the environmental media of concern, discussed above, the potential exposure pathways of concern that have been considered in the current SSRA are:

- ingestion of soil/dust (outdoors);
- inhalation of soil/dust (outdoors);
- dermal contact with soil/dust (outdoors); and,
- ingestion of groundwater as a potable water source.

Exposure via Soil/Dust (Outdoors) from the Sound-Sorb Berm

There is the potential for nearby residents, workers at the OSGC, visitors and members of the OSGC, and trespassers to be exposed to SOPCs in the berm. Exposure could occur by ingestion, inhalation and dermal contact with SOPCs in the berm. However, these exposures are expected to be negligible for several reasons:

- the Sound-Sorb material used to construct the berm is covered in a layer of compost material, approximately 15 to 30 cm deep in places;
- the compost over the Sound-Sorb is covered with naturally-occurring vegetation during the spring, summer and autumn months and by snow during the winter;
- the coverage of the berm material would limit the potential for the creation and movement of dust off the berm to a location where people are present;
- the nature of the site itself, as a shooting range, would limit the number of people in contact with the berm or the Sound-Sorb material. Residents do not live in close proximity to the Site. According to the manager of the OSGC, workers do not conduct any maintenance activities on the berm itself, and members of the OSGC or other visitors are unlikely to walk near the berm. Similarly, trespassers are unlikely to walk on or near the berm during daylight, due to shooting activity, nor at night due to its remote location. There has been no evidence or reports of trespassing on or near the berm.

In summary, incidental ingestion and inhalation of, and dermal contact with soil/dust originating from the berm were considered negligible pathways for exposure and were not quantitatively evaluated in the current SSRA.

Exposure via Groundwater as a Potable Water Source

There is the potential for nearby residents, workers at the OSGC, and visitors and members of the OSGC to be exposed to SOPCs in groundwater which serves as a drinking water source. However, this exposure is expected to be negligible for the following hydrogeological reasons (GLL, 2004a):

- SOPCs are present in the shallower groundwater aquifer beneath the OSGC;
- the shallow and deep groundwater systems are isolated from one another in the area of the Site, thereby eliminating the possible leaching of SOPCs from the berm *via* the shallow groundwater into the deeper groundwater aquifer;
- the nearest drinking water well is located 625 metres southeast of the berm while the groundwater from the OSGC moves towards the north; and,
- the nearest drinking water well north of the berm is approximately 1 km away and is screened in the deeper groundwater aquifer.

In summary, exposure *via* groundwater as a potable water source was considered a negligible pathway for exposure and was not quantitatively evaluated in the current SSRA.

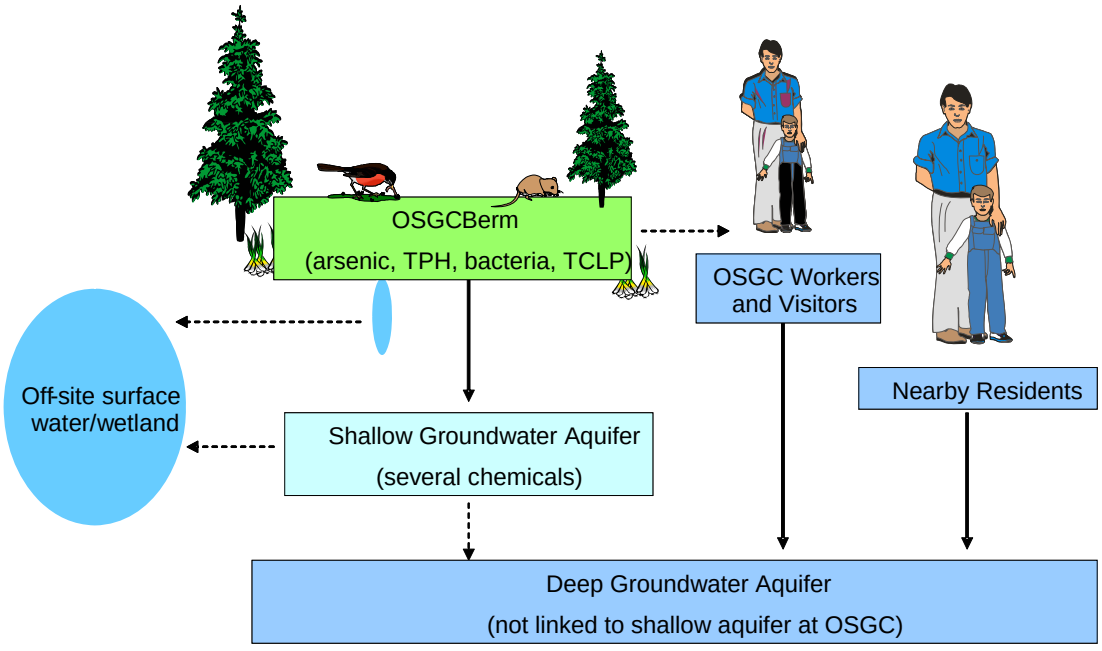

Figure 3-4 Potential exposure pathways; solid arrows represent complete pathways and dashed arrows represent incomplete exposure pathways

3.2 Uncertainty Analysis

In any risk assessment, the findings are based on available data from the specific study area, and the scientific literature, in conjunction with a number of assumptions. Every effort is made to ensure these assumptions and data adequately represent conditions at the Site. However, data and scientific understanding of key environmental processes and factors can often be limited, resulting in uncertainty in the assessment. Varying degrees of uncertainty are introduced at all stages of the risk assessment process. In order to clearly interpret the results of any risk assessment, the major sources of uncertainty must be acknowledged and documented. Where uncertainty exists, assumptions are made, and data are selected so as to err on the conservative side. This ensures that potential impacts are much more likely to be overestimated rather than understated. This precautionary approach is in accordance with the ultimate goals of risk assessment - protection of human health and the environment. As with the sources of uncertainty, it is important that key assumptions used in the assessment also be acknowledged, and documented, and that their impact on the results of the assessment be clearly understood.

Some key sources of uncertainty associated with the current human health risk assessment included:

- It is assumed that the samples collected from the berm are representative of the entire berm. Composite samples were taken by GLL which gives a general indication of concentrations in each half of the berm. MOE sampled two cores of the berm.
- Not all substances analysed for in the berm or in groundwater have human health-based criteria. Because there are no complete exposure pathways between SOPCs in the berm or groundwater and humans, this should not influence the SSRA results or conclusions.
- The hydrogeological investigation suggested that shallow and deep groundwater are not connected in the vicinity of the OSGC. It is assumed that this condition remains between the OSGC and the nearest down-gradient drinking water well.
- According to information provided by the OSGC, neither workers nor members of the OSGC are in close proximity to the berm. Therefore, it was assumed that there was no direct contact between the berm and any person (work, member, visitor, trespasser, nearby resident).

4.0 ECOLOGICAL RISK ASSESSMENT

Many of the techniques used in human health risk assessment are also employed in ecological risk assessment (ERA). There is, however, consideration of several distinct receptor types - aquatic organisms, including fish, invertebrates and plants, and terrestrial organisms, including mammals, birds, plants, and soil-dwelling organisms. The following describes specific methodologies related to ERA.

The ERA was conducted in compliance with the risk assessment guidance from regulatory agencies including the Ontario Ministry of the Environment (MOEE, 1996b, 1997), the Canadian Council of Ministers of the Environment (CCME, 1996), and the United States Environmental Protection Agency (U.S. EPA, 1998). The basic steps in an ERA include: receptor characterization, exposure assessment, hazard assessment and risk characterization (Figure 4-1).

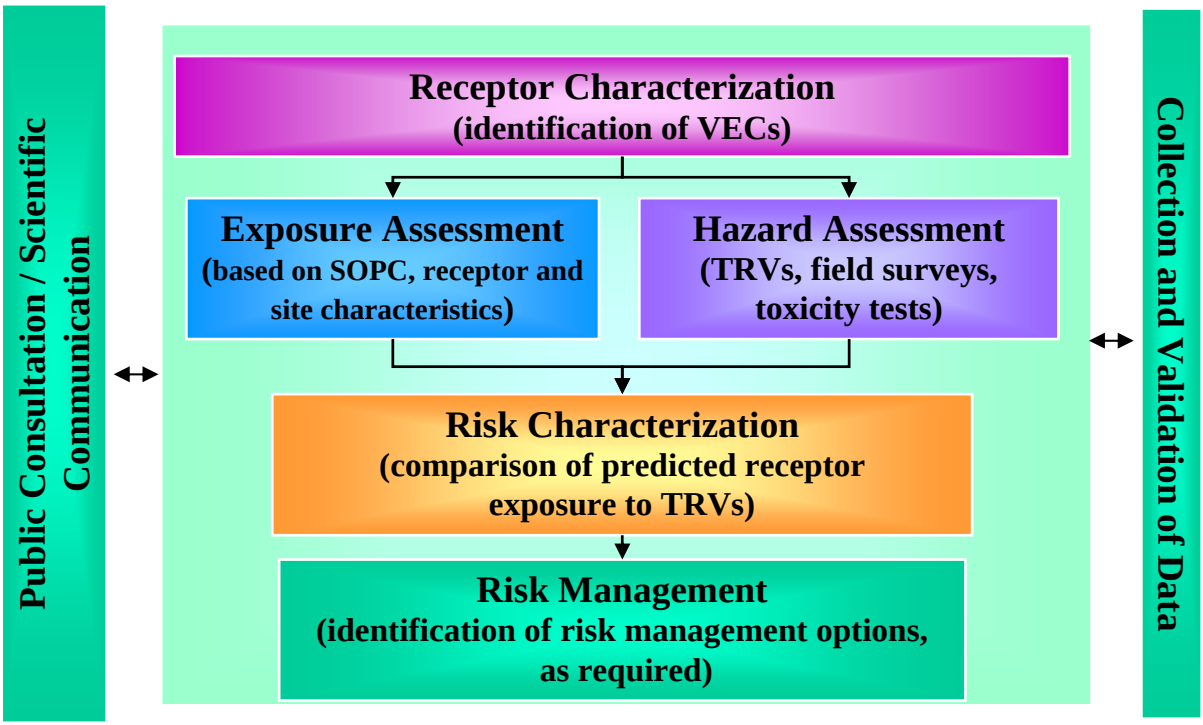

Figure 4-1 The basic steps in ecological risk assessment

4.1 Receptor Characterization

A receptor is defined as an organism or group of organisms that have the potential to be affected by SOPCs (Environment Canada, 1994). Receptors selected for the SSRA represent valued ecosystem components (VECs). A VEC is an ecological species, population or community that is important to people, has economic and/or social value, is ecologically significant and can be evaluated in the risk assessment (adapted from CCME, 1996).

Given the large number of species that could be found at a site, representative receptors are selected based on several criteria (CCME, 1997; Suter, 1989), including:

- Threatened or endangered species;
- Sensitivity to the SOPCs from the berm;
- Biological and ecological relevance;
- Ability to measure or predict effects; and,
- Social relevance (species of recreational, commercial or social importance).

VECs rarely meet all of the above criteria. For example, no rare, threatened or endangered species are expected at the site (Appendix B). However, effort is made to select VECs that meet several of these criteria. In addition, representative receptors are selected for each feeding guild (*e.g.*, insectivorous small mammal, herbivorous small mammal, *etc*.) and these receptors can be considered surrogates for other species within that guild (*e.g.*, the short-tailed shrew may be considered a surrogate for other insectivorous small mammals).

Our current understanding of the site precludes consideration of aquatic organisms, as there is no permanent surface water at the Site. In addition, there are several small ponds and wetland areas in the vicinity of the Site. However, due to the surface geology and hydrology in the area, the groundwater is not expected to contribute to any surface water bodies (GLL, 2004a; Appendix A). For these reasons, no aquatic or wetland receptors were considered in the current SSRA (see Figure 3-4).

In the terrestrial environment, VECs may include terrestrial plants, soil invertebrates, birds and mammals (Figure 3-4). Terrestrial plants, earthworms and other ground invertebrates are in contact with surface soils. The levels of SOPCs in surface layers of the berm should be low enough to allow plants and earthworms (representative of soil invertebrates) to survive, grow and reproduce. The plants on the berm have shallow root systems, and earthworms remain in the shallow aerobic portion of the berm. Therefore plants and earthworms would be exposed primarily to chemicals in the compost material which is 15 to 30 cm deep over the Sound-Sorb material. In fact, during a visit to the site by members of the risk assessment team (July 8,

2003), it was noted that the berm was covered in naturally-occurring vegetation. In addition, numerous earthworms were observed consistently in the compost layer when the surface few centimeters of compost were moved to the side from several small areas on the berm (*e.g.*, each area was approximately 500 cm^2). Therefore, qualitatively at least, it appeared that the surface compost layer of the berm had an abundant earthworm population.

Given the surrounding habitats and terrain, a variety of birds and mammals might be expected to use the Site. However, the berm itself does not provide significant or exceptional habitat to local wildlife. The surface area of the berm is approximately 0.3 ha (90 m long, 20 m wide and 15 m high). Examples of animals with larger home ranges would include raccoons (5 to 5000 ha), red fox (700 ha), white-tailed deer (59-520 ha), red-tailed hawk (230 ha), *etc.* (U.S. EPA, 1993; Sample and Suter, 1994). Clearly, the berm would represent a small fraction of the home range of these species, and therefore it is not necessary to consider species such as these further.

Small mammals and birds with small home ranges which typically are evaluated in an ERA include voles (herbivore) and shrews, moles and robins (insectivores) and mice (omnivore). The meadow vole (*Microtus pennsylvanicus*) prefers grassy fields, marshes and bogs and eats many grasses, clover and plantain (Whitaker, 1996). The northern short-tailed shrew (*Blarina brevicauda*) prefers forests, wetlands and grasslands, and is most abundant in hardwood forests with deep litter and humus (Sample and Suter, 1994). They prefer nests under a log or stump (Whitaker, 1996). Moles (such as the Hairy-tailed Mole *Parascalops breweri*) prefers woods with well-drained soil, but may be found also in lawns and golf courses adjacent to woods (Whitaker, 1996). The American robin (*Turdus migratorius*) prefers to forage in fields, orchards and lawns with short grass (Sample and Suter, 1994). The deer mouse (*Peromyscus maniculatus*) prefers brushy areas and woodlands and often is highly arboreal. It eats seeds, fruit, caterpillars and other insects (Whitaker, 1996). The berm at the OSGC does not provide preferred habitat to any of these species.

In addition, most mammals (with the exception of meadow vole and moles) and birds primarily forage for food during the daytime. Given the activities that occur at the site (*i.e.,* firing rifles, shooting skeets and targets, *etc*.) and the level of noise at the OSGC during the daytime, it is unlikely that wildlife would frequent the area for a significant amount of time either to forage for food or to nest. In addition, the SOPCs in the berm (arsenic and TPH) are not expected to accumulate in plants or earthworms to a significant degree. Therefore, dietary exposures to wildlife are expected to be low. Therefore, in summary, small mammals and birds were not selected as VECs because: the berm is small relative to the home range of most species; the noise at the site during the day would discourage its use by wildlife; the low habitat suitability of the berm for small mammals and birds with small home ranges; and SOPCs are not expected to accumulate in wildlife food (*e.g*., vegetation, earthworms).

Amphibians and reptiles were not included in the ERA. Amphibians are not assessed because the sensitive life stage for amphibians is the tadpole, which is exposed to chemicals in the aquatic environment. There are no significant surface features at the site which could provide breeding habitat for amphibians, are which are likely to be significantly influenced by substances within the Sound-Sorb berm.

Reptiles were excluded from the assessment because of a lack of toxicity data. Even toxicity tests cannot be conducted because there are no standardized tests for reptiles (Meyers-Schone, 2000). Because relevant toxicity data do not exist, ERAs cannot model risk to reptiles. In many cases, an ERA will focus on reptilian species only when there is a threatened or endangered reptile at the site (Meyers-Schone, 2000). In the area around the OSGC, there are no rare, threatened or endangered reptilian species (Appendix B). Therefore, reptiles were not assessed in this ERA.

In summary, VECs selected for evaluation in this ERA include:

- The vegetation community on the berm; and,
- Earthworm populations in the berm.

4.2 Exposure Assessment

The first step in the exposure assessment is to revisit the SOPCs screening (from Section 2.4.1) to identify SOPCs specific to the ERA VECs (vegetation and earthworms). The SOPCs in the OSGC berm (from Section 2.4.1), to which ecological VECs may be exposed, include:

- Total petroleum hydrocarbons (TPH).

No exposures of VECs to SOPCs in groundwater were estimated because it is the current understanding that the probability of a connection between groundwater and surface water is low (Appendix A).

Total Petroleum Hydrocarbons

TPH was detected (3,400 µg/g) in one sample of the berm at depth (0.8 to 1.0 m) at a concentration greater than the MOE Table A criterion (1,000 µg/g). Further review of the results of the berm sampling data revealed no exceedance of the Table A criteria by any TPH component such as PAHs or BTEX compounds. Based on the depth at which TPH was detected in the berm, the lack of PAH or BTEX compounds detected above the Table A criteria, and the abundance of plants and earthworms at the berm, TPH was not considered further as an SOPC for plants or earthworms.

Summary

Although SOPCs (TPH, bacteria and fungi) were identified in the initial screening (Section 2.4.1), none were retained for quantitative evaluation in the SSRA. The layer of compost above the Sound-Sorb may decrease or prevent exposure of VECs to the Sound-Sorb, and therefore no adverse effects would be expected. In fact, qualitative field observations of plants and earthworms support this conclusion.

4.3 Assumptions and Uncertainties

Similar to the human health risk assessment, assumptions were made in the ERA. Therefore, it is important that key assumptions be acknowledged, and their impact on the results of the ERA be clearly understood. Some key sources of uncertainty associated with the current ERA included:

- It is assumed that the samples collected from the berm are representative of the entire berm. Composite samples were taken by GLL which gives a general indication of concentrations in each half of the berm. MOE sampled two cores of the berm. The actual concentrations across the berm could be higher or lower than those measured by GLL and MOE. However, this should not influence the results or conclusions of the risk assessment.

- Not all substances analysed for in the berm or in groundwater have ecological-based criteria. Because the VECs are plants and earthworms, and both were abundant, this should not influence the SSRA results or conclusions.
- The hydrogeological investigation concluded that shallow groundwater is not connected to surface water bodies (including wetlands) in the vicinity of the OSGC. Therefore, groundwater was not considered in the ERA.
- It is assumed that the current configuration of the berm remains, and that no future activities alter the structure of the berm in such a way as to increase the potential for exposure to wildlife (*e.g.,* flattening/spreading of berm material over a larger area).
- It is assumed that there will be no addition of lighting or active watering of the berm area, which could increase the attractiveness of the area for wildlife (*e.g.,* birds or bats). These activities are unlikely, as there is no need for lighting or watering in this area of the gun club.
- Not all MOE Generic Criteria include consideration of potential wildlife exposures and risks. In addition, they are dated (from 1996 or earlier), and there may be newer toxicological information available. However, these are the criteria which must be used in Ontario. This uncertainty is unlikely to change the results or conclusions of the risk assessment, due to the low potential for exposure.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The SSRA considered the impacts to humans and ecological receptors, both on and off the Site, of various substances that may have originated from the berm. The SSRA did not address other concerns related to Sound-Sorb or its use at other gun clubs, or the impacts associated with the use of compost. That is, this SSRA was a site-specific evaluation of current conditions at the OSGC, and the results presented herein should not be applied to other gun clubs or uses of Sound-Sorb.

Based on our current understanding of the conditions at the OSGC, the site does not satisfy the criteria for a "potentially sensitive" site. SOPCs were identified in the berm (acylamide monomer, TPH, and bacteria and fungi).

Four main types of human receptors were considered potentially exposed to SOPCs originating from the berm: off-site residents; workers at the OSGC; members of or visitors to the OSGC; and, trespassers. However, all exposure pathways were considered incomplete because:

- the Sound-Sorb material used to construct the berm is covered in a layer of compost material, approximately 15 to 30 cm deep;
- the compost over the Sound-Sorb is covered with naturally-occurring vegetation during the spring, summer and autumn months and by snow during the winter;
- the coverage of the berm material would limit the potential for the creation and movement of dust off the berm to a location where people are present;
- the nature of the site itself, as a shooting range, would limit the number of people in contact with the berm or the Sound-Sorb material. Residents do not live in close proximity to the Site. According to the manager of the OSGC, workers do not conduct any maintenance activities on the berm itself, and members of the OSGC or other visitors are unlikely to walk near the berm. Trespassers are unlikely to walk on the berm;
- SOPCs are present in the shallower groundwater aquifer beneath the OSGC;
- the shallow and deep groundwater systems are isolated from one another in the area of the Site, thereby eliminating the possible leaching of SOPCs from the berm *via* the shallow groundwater into the deeper groundwater aquifer;
- the nearest drinking water well is located 625 metres southeast of the berm while the groundwater from the OSGC moves towards the north; and,
- the nearest drinking water well north of the berm is approximately 1 km away and is screened in the deeper groundwater aquifer.

Without any complete exposure pathways from SOPC to human receptor, there can be no health risk.

Two main types of ecological receptors were considered potentially exposed to SOPCs in the berm: soil invertebrates (earthworms); and plants. However, exposures were considered insignificant because:

- the Sound-Sorb material used to construct the berm is covered by a layer of compost (15 to 30 cm), thereby restricting the exposure of plants and earthworms to SOPCs within the berm; and,
- plants and earthworms were both abundant on and in the berm.

In addition, the hydrogeological investigation concluded that shallow groundwater is not connected to surface water bodies (including wetlands) in the vicinity of the OSGC. Therefore, the ERA concluded there were no unacceptable ecological risks.

In addition, as a result of the SSRA findings, the following recommendations are made:

- Particular attention should be paid to chloroform concentrations in MW4 to determine whether concentrations decrease. This would support the assumption that chloroform is present as a byproduct of disinfection of the well prior to sampling in Sweep 2.
- Visual inspection of the berm on a regular basis (annually) to identify and repair unvegetated cracks and trenches is desirable; however, these cracks and trenches are not likely to present unacceptable risks given the use and characteristics of the berm.

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8.0 DOCUMENT SIGN-OFF AND CERTIFICATIONS

This report has been performed in accordance with the *Guideline for Use at Contaminated Sites in Ontario* and in accordance with accepted practice and usual standards of thoroughness and competence for the profession of toxicology and environmental risk assessment. The information, opinions and recommendations provided within the aforementioned report have been developed using reasonable and responsible practices, and the report was completed to the best of our knowledge and ability. Cantox Environmental Inc. does not attest to the quality or completeness of work conducted by other consultants; however, the risk assessment (including the hydrogeological report) has been peer reviewed by an independent consultant.

In addition:

- Elliot Sigal and Ruth Hull are qualified persons, as defined in section 168.1 of the Environmental Protection Act, and have the qualifications required by Part II Section 6 of Ontario Regulation 153/04;
- The risk assessment team included members with expertise in all of the disciplines required to complete the risk assessment in accordance with O. Reg. 153/04;
- The opinions expressed in the risk assessment are scientific opinions made in accordance with generally accepted principles and practices as recognized by members of the science profession or discipline practicing in Ontario;
- To the best of our knowledge, the certifications and statements in this risk assessment are true as of March 10, 2005; and,
- By making these certifications in this risk assessment report, we make no express or implied warranties or guarantees.

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